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APPLIED THEORY OF PLASTIC DEFORMATION OF BEAMS

Yu. I. Yagn and Ye. N. Tarasenko
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/In this report, of which the following is a digest, an important nonlinear differential equation is employed in an actual applied case of plastic deformation, and its solution is indicated by current methods./

In G. Yu. Dzhanelidze's work (1) the applied theories of elastic deformation of beams were widely generalized on the base of essential kinematic schemes that take into account the effect of warping of cross sections caused by twisting. He proposed, in a study of deformation beyond the elastic limit, a simplified kinematic model constructed on the assumption that the cross sections remain plane during all forms of deformation of a beam, including torsion.

However, experiments clearly reveal a strong warping of the cross sections during all stages of plastic torsion. In this case the observed forms and dimensions of the warping of cross sections approach those obtained for the same degree of torsion in the elastic stage of deformation.

Thus, we are compelled to recommend that in any construction of an applied theory of plastic deformation of beams one must preserve the kinematic scheme that applies, or responds, to the elastic stage, as was also advocated by V. V. Novozhilov (2).

When these recommendations are followed, we find the general equation describing the kinematic picture of deformation to be the following nonlinear one:

$$\ddot{\tau}\dot{\tau}^2 + A\ddot{\tau}\tau^2 + B\ddot{\tau} + C\dot{\tau}^2\tau + D\tau^3 + E\tau + G = 0$$

where tau τ is the relative angle of twist and A, B, C, D, and E are constants. This equation can be approximately solved by B. G. Galerkin's variational method or by numerical integration.

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This equation results from the simultaneous solution of the following set:

$$\varepsilon_z = \varepsilon + k_1 y - k_2 x + \dot{\tau}\varphi$$
$$\gamma_{xz} = \tau\left(\frac{\partial \varphi}{\partial x} - y\right) + \bar{\gamma}_{xz}$$
$$\gamma_{yz} = \tau\left(\frac{\partial \varphi}{\partial y} + x\right) + \bar{\gamma}_{yz}$$

where ε_z is the longitudinal relative elongation; γ_{xz} and γ_{yz} are the angular displacements in the longitudinal planes parallel to the principal central axes of inertia of the cross section; ε is the average value of ε_z over the cross section; K_1 and K_2 are the components of the curvature of the beam's axis in the planes of the principal central axes of inertia; x and y are the coordinates of this system; φ is a function of torsion satisfying the equation $\Delta\varphi = 0$ and the boundary conditions $\partial\varphi/\partial n = y\cos(n,x) - x\cos(n,y)$ and $\int_{\Omega} \varphi \, d\Omega$ for the determination of the constant; $\bar{\gamma}_{xz}$ and $\bar{\gamma}_{yz}$ are the additional angular displacements over and above those displacements that are due to pure torsion. The presence of these terms distinguish our equations from the corresponding ones used by G. Yu. Dzhanelidze for the elastic stage.

[The remainder of the article reduces this set to the nonlinear equation, after suitable transformations and eliminations, with approximations and neglect of high-order terms; A, B, C, D, E are lumped constants.]

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2. V. V. Novozhilov. Fundamentals of the Nonlinear Theory of Elasticity (Osnovy nelineynoy teorii uprugosti), Section 49, 1948.

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